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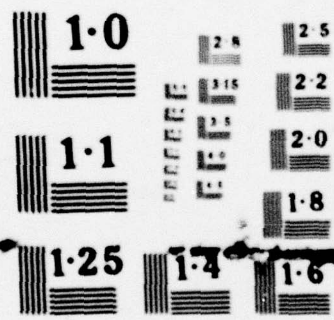
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OPERATION SNAPPER

Project 4.5

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FLASH BLINDNESS

REPORT TO THE TEST DIRECTOR

by

Victor A. Byrnes
Colonel, USAF (MC)

March 1953

Cooperative Project
USAF School of Aviation Medicine
and
Army Medical Center

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ABSTRACT

This project was designed to determine the effect of the flash of atomic detonations at night upon the ability of military personnel to carry out their assigned tasks when such tasks involve the use of vision.

It is considered that in general three types of visual tasks are involved in military operations: (a) reading of instruments in ships, aircraft, tanks and vehicles; (b) central acute vision at low levels of illumination; (c) peripheral vision at very low levels. After an atomic flash each individual involved in such military visual tasks would attempt to return to seeing under the light level then available to him. The time required for him to see under each of these circumstances was determined.

Subjects were located approximately 10 miles from the detonation point. They were dark adapted in a light-tight trailer. Their eyes were exposed to the atomic flash by a shutter arrangement. Some eyes were protected by a red filter and some eyes were unprotected. The red filter was chosen because it selectively filters the high short-wave content of the early part of the detonation and because individuals wearing it can see red lighted instruments in vehicles, ships, tanks and aircraft.

Because of the small number of observations permitted, the results of this experiment should be regarded as approximations. Future tests will be necessary to determine response time values.

Experimental results were obtained at approximately 10 miles from the detonation. The values indicated below are in terms of the time lapse between detonation of the weapon until the indicated function is resumed.

Reading Red-lighted Instruments - Average time to the first correct instrument reading was 23.2 seconds for the unprotected pilot and 8.8 seconds for the protected pilot when red flood lighting was available in addition to the red internal lighting. When only the red internal lighting was available, the average time to the first correct reading, unprotected, was 105 seconds; protected, 89 seconds.

<u>Central Vision Under Reduced Illumination</u> - Nyctometer tests were used and it was found that reasonably good photopic vision returned in 132 seconds in the unprotected eyes and in 111 seconds in those protected by red filters.

<u>Peripheral Vision Under Low Levels of Illumination</u> - At 0.001 foot-candles of illumination (approximately that of moonlight) form could be distinguished in about 5 minutes by the unprotected and in about 4

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minutes by those protected by red goggles. At 0.00001 foot-candle (approximately that of a starlit night) form could be distinguished in about 11 minutes, unprotected; 5½ minutes protected by red goggles.

Attention is invited to the fact that retinal burns can be produced by atomic blasts and that these burns are largely independent of distance except for size of the burn produced; that the reported results on flash blindness are for a distance of approximately 10 miles and that additional tests are required to get reliable data which can be accurately correlated with other physical data.

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PREFACE

The purpose of this report is to give operational units an estimate of the length of time personnel would be unable to see well enough to carry out their assigned tasks if they were unexpectedly exposed to an atomic flash.

It is emphasized that results reported herein are based on only a small number of observations and are therefore subject to revision when future tests have supplied more data. Results are furnished at this time to give commanders a rough estimate of these effects for planning purposes.

ACKNOWLEDGMENTS

The project officer desires to express appreciation to the following commands for their outstanding cooperation in furnishing the personnel who made completion of this study possible:

To Crew Training Air Force for furnishing test subjects at both Luke and Nellis Air Force Bases and for the assistance of Colonel Jack Bristow, ophthalmologist at Nellis Air Force Base.

To Strategic Air Command for assistance of Lt Colonel Richard Miller and Lt John W. Watson.

To Air Training Command for the assistance of Lt Jerry H. Jacobson.

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And finally to the personnel of the School of Aviation Medicine who worked long and hard on the preparation of the many details involved in this research project. Special thanks are due Captain Mathew R. Wilson and Captain Gustav C. Bahn for their efforts.

Without the efforts of this large group and the thoughtful assistance of personnel at the test site, this project could not have been completed.

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DEFINITIONS

(Definition of Terms Used in This Report as Applied to This Experimental Situation)

1. Adaptometer - An instrument used to measure the state of adaptation to light of the human eye.
2. Fovea - The anatomical area of the eye which is the site of the visual end organs capable of giving the individual acute vision.
3. Nyctometer - An instrument designed to measure the dark adaptation rates of the cones in the central area of acute vision.
4. O.D. - Ocula dextra--right eye.
5. O.S. - Ocula sinistra--left eye.
6. Paracentral Vision - Vision peripheral to the central area of very acute vision made possible by the fovea.
7. "Protected" - Used in this report to indicate an eye behind an ophthalmic filter. This filter absorbs radiant energy in certain wavelengths, therefore, the eye behind it is "protected."
8. Red Filter - A red lens which filters out certain amounts of light in various wavelengths by absorption. Such lenses are all ophthalmic filters.
9. Red Lighting - Illumination by the use of red light.
10. Red Internal Lighting - Illumination of instrument dials by lights inside the instruments rather than by external flood lighting.
11. Scotoma - A blind area in the visual field. It may be partial or complete; temporary or permanent.
12. Scotopic Vision - The type of vision which an individual has when light intensity is lower than moonlight. The central portion of the retina cannot function at this light intensity, so there is a scotoma in the visual field. Hence the term "scotopic vision."
13. Stereocampimeter - An instrument designed to map out the sensitivity of the central area of vision. It is useful in mapping scotomata.

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FLASH BLINDNESS

1.0 INTRODUCTION

There are essentially two types of night vision tasks which are of interest to the services. One of these is the situation in which an individual is looking at illuminated dials (usually red lighted) aboard ship, as pilot of an aircraft or driver of a tank. He may be exposed to a bright flash of light such as that produced by an atomic detonation and then return to his task of attempting to read his illuminated instruments.

The other type of night vision task is that of the soldier or airman on the ground. His visual task is carried out with only the illumination provided by the moon or stars. If he is exposed to the flash of an atomic bomb he returns to his task of trying to see objects under this dim illumination. This task is further subdivided into two because vision at moonlight levels permits the use of central (photopic) vision. When there is only starlight available all vision must be peripheral (scotopic) vision.

Tests were therefore designed to procure data on all three of these visual tasks; the reading of red lighted instruments, the recognition of objects by moonlight intensities and the recognition of objects under starlight intensities.

1.0.1 Objective

This research was conducted to determine to what degree the flash of an atomic detonation impairs the vision and reduces the efficiency of military personnel during night operations. The effect during daylight operations has been previously studied 1/. Observations were made which were intended to reveal the evolution, degree, and duration of the reduced vision. An attempt was made to evaluate the protection afforded by the use of red goggles.

2.0 INSTRUMENTATION

Since most of the detonations took place in the daytime, it was necessary to use some means of exposing the eyes while the subject was dark adapted and had the normal dilated pupils that go with the night seeing situation. This is, of course, necessary in order to obtain useful information applicable to night operational conditions.

1/ Flash Blindness Study, Project 4.3, Operation BUSTER

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A light-tight trailer was used to house the observers so that dark conditions could be simulated. It was set up approximately 10 miles from detonation point. Along the side of the trailer were 12 ports fitted with shutter devices for exposing the eyes of the observers. The shutters were constructed in such a manner that the left eye only was exposed to the flash while the right eye was used to fix the position of the eyes by regarding a luminous fixation object. The shutters opened after a 48 millisecond mechanical delay by a "blue-box" photoelectric device and suitable relays. The shutters closed again 2 seconds later. Timing of the tests was begun with the closure of the shutters. Three types of equipment were used to examine the observers after exposure.

Zeiss nyctometers were used to tabulate the return of mesopic vision following which the observers reported their ability to see Landolt rings in adaptometers of known luminosity.

Another group of observers were asked to report readings on red-lighted aircraft instruments. Return of the ability to read these instruments was recorded in time.

The size, intensity, and duration of the temporary scotoma produced by the flash were measured in a third group of observers by the use of stereocampimeters.

During the exposure, half of the observers in each group wore protective red goggles. (Goggle, dark adaptation, Type E-1, Spec. No. 94-3142).

3.0 OPERATIONAL PROCEDURE

The tests were conducted during the detonations on 22 April and 1 May (Shots 3 and 4). The subjects were allowed to become dark adapted for wearing dark adaptation goggles for 30 minutes and then by remaining for 30 minutes in the dark in the trailer before the detonation. A shutter in front of the left eye of each observer opened between 46 and 52 milliseconds (average 48 milliseconds) after the beginning of the flash and closed after 2 seconds. No attempt was made to control the blink reflex. This reflex varies only slightly in individuals and averages 100 milliseconds in duration. At the end of this period the lids are closed admitting about 1 per cent of the light to the eyes. The shutters remained open 2 seconds which allowed maximum bleaching of the retina and then the shutters closed. There would have been no purpose served by controlling the blink reflex since it is a normal part of man's adaptive response to bright light. There is more variation in his retinal recovery period than in his blink time. Therefore, the assessment of the total response is more useful in this experiment than an analysis of the variables in the experiment. The objective of the study is an answer to an operational problem and not a purely scientific study.

Following closure of the shutters the observers turned to the three groups of testing devices for examination.

3.0.1 Nyctometers and Adaptometers (Four Subjects)

The observers placed their eyes in position on the nyctometer, and as soon as able, began to read the larger letters of the visual acuity charts. They read the progressively smaller letters as soon as these became visible. The progress was timed from the exposure to the flash. This reading gave cone adaptation levels. After 4 minutes, or after the subject had read all the characters (whichever came first) the observer was directed to look at the adaptometers reporting perception of the ring and perception of the break in the ring of each of the three adaptometers. These were also recorded in time from exposure. This was a rod perception task.

3.0.2 Instrument Reading (Four Subjects)

Standard aircraft instruments were used since the observers were pilots. These instruments are similar in size and design to instruments used in tanks, wheeled vehicles, and aboard ships. Two types of red colored illumination were used. First the instruments were illuminated by a red flood light as well as the red instrument lights. After the observer could read the instruments without delay, the flood light was turned out and a determination was made when the observer was able to read the instruments without delay using the internal lighting, alone.

3.0.3 Scotometry (Four Subjects)

With the use of hand-held stereocampimeters the size and intensity of the temporary scotomata were determined.

3.0.4 Red Goggles

Red filters were used on one-half of the subjects in order to determine the usefulness of such filters as protective devices against the effects of atomic flash. Their selection for this purpose was based on the fact that they permit the passage of red light from red-lighted instruments. They can be safely worn by pilots flying on instruments. In addition, they absorb all the short-wave portion of the spectrum which early in the flash contains a large amount of energy because of the high color temperature. They actually transmit about 22% of the energy present in the visible and infra-red portions of the spectrum during the phase of the detonation in which the eyes in this experiment were exposed. (Based on the old data in the book on the Effects of Atomic Weapons.)

4.0 RESULTS

Only two detonations were used for this test for the reason mentioned under paragraph 4.0.2. Consequently an insufficient number of test findings are available to give precise results. Data available are discussed below and tabulated in Tables 1, 2 and 3.

The nyctometer tests showed that the average time required for the unprotected individual to regain good mesopic vision was 132 seconds and for those protected by red filters it was 111 seconds. The adaptometers indicate that the average of the individuals tested regained vision for distinguishing form at 0.001 foot-candle of illumination (approximately that of moonlight) in 310 seconds for unprotected, 245 seconds for protected; at 0.00001 foot-candle of illumination (approximately that of a clear starlit night) in 671 seconds unprotected, 325 seconds protected.

The recovery of useful vision for reading red-lighted instruments was very rapid. The average time to the first correct instrument readings are quoted. For the situation in which both red flood lighting and internal red lighting were used, for the unprotected pilot, 23.2 seconds; for the protected pilot (red filters), 8.8 seconds. Where only the internal red instrument lighting was used, average time to the first correct reading, unprotected, was 105.6 seconds; protected, 89.5 seconds. This indicates the shorter periods when the eye is protected by a red filter. It also shows the value of the higher intensity red flood lighting in shortening the period in which an individual is unable to read his instruments.

4.0.1 Scotometry

Immediately after exposure the subjects described a large white or yellow-white area of absolute scotoma. This was recorded as irregular in shape and as much as 15 to 25 degrees in size. Within 30 seconds this decreased in size to 4 to 6 degrees and roughly spherical in shape. The density of the scotoma became progressively less as the size gradually diminished to one or two degrees after 5 to 6 minutes. At this time the area was described as "hazy" by one of the observers and the others indicated the scotoma was relative. After 6 minutes most observers had difficulty in outlining the involved area, although one subject was able to outline a 6 degree scotoma after 11 minutes.

4.0.2 Thermal Effects

which shot?

Two of the subjects developed blanched areas of the retina following exposure to the flash. Only one of these men showed an impairment of vision and complained of a scotoma. This man showed a small area of retinal edema with a central blanched area. He complained of a "spot" in the exposed eye and described a positive scotoma, but no actual discomfort was experienced. Visual acuity remained 20/15, O.D., O.S.,

and O.U. Visual fields in this case revealed a small absolute paracentral scotoma about 2 degrees in diameter in the area corresponding to the site of the retinal lesion. The paracentral vision and the retinal lesion gradually improved and recovery was complete.

The second individual gave no evidence of any visual malfunction. Careful visual field examination showed no scotoma. Examination of the retina of this man revealed a small area of retinal edema. Both of these men were observed until they completely recovered. Neither has any visual impairment, visual field defect, or change in the fundus of the eye. Their injuries were minimal and both subjects are now completely recovered.

5.0 DISCUSSION AND CONCLUSIONS

As a result of the discovery of the two cases of retinal injury, the tests were discontinued after two shots (Nos. 3 and 4).

The mechanical delay in the shutter mechanism was the cause of a good deal of difficulty. It was considered important to know what would happen in a real life situation if an individual working in the dark was exposed to an atomic flash. For this reason a shutter release mechanism was built to trip the shutters so as to open simultaneously with the detonation of the bomb. Unfortunately, however, it was not possible to get a zero minus one second signal with an accuracy greater than plus or minus 100 milliseconds. It was therefore necessary to use a photoelectric system with an average delay of 48 milliseconds after detonation. The lids closed within about 100 milliseconds after the shutter opened, so the eyes were exposed during the 50-150 millisecond portion of the energy curve rather than the 0-100 millisecond portion which would have been more desirable.

Preliminary data furnished by the Armed Forces Special Weapons Project indicate that more radiant energy was present during the period used than would have been present during the 0-100 millisecond period. It can, therefore, be expected that slightly shorter times might be found in the real life situation than are indicated in this report.

Two of the subjects did develop retinal burns. Therefore, the indications are that because the dilated pupil admits approximately 50 times the light which is admitted by the daylight constricted pupil, the flash of an atomic detonation presents a real danger to the retina of an individual whose eye is adapted for night vision and who is looking in the direction of the flash. Distance will only decrease the size of the retinal burn and not its intensity (with the exception of attenuation by the atmosphere and degradation of the retinal image by optical defects).

In spite of the occurrence of a retinal burn, in most cases this injury would not incapacitate the individual, and unless he were looking directly at the point of detonation, the small scotoma produced would not in itself constitute any significant disability. However, such a burn incurred in the fovea would be serious. The probability that an individual would be looking at the exact flash location is very small.

The military personnel operating under conditions of reduced illumination of 0.15 foot-candle (on nyctometer) would regain useful vision in about 2 minutes. (Subjects were 10 miles from the atomic detonations of about nominal yield.) Those operating under even more reduced illumination, approximately moonlight (0.001 foot-candle), would regain useful vision in about 5 minutes. Individuals using internally red illuminated instruments and wearing no protective devices would on the average require about 1 3/4 minutes before they can again read those instruments. If red flood lighting is used, this time can be reduced to about 23 seconds. If the subject wears red goggles the time will be reduced to about 1½ minutes for the internally illuminated instruments and to 8.8 seconds when red flood lighting is available.

The use of red goggles gave enough protection to the eyes of the observers so that they regained the use of their eyes more rapidly. None of the individuals protected with red goggles received a retinal burn. This is not surprising since the filters absorbed a large per cent of the incident light energy during the period of exposure. The number of instances is too small for this to be statistically significant.

6.0 RECOMMENDATIONS

The following recommendations apply to the use of the eyes at night. The daytime situation presents no particular problem from the standpoint of flash blindness.

It is recommended that:

Individuals who can perform military tasks wearing red filters, do so if there is a possibility of an atomic explosion in their vicinity at night. Such personnel would be largely limited to those observing red-lighted instruments.

Additional studies be carried out to determine other filters which may be added to the red filter to increase its effectiveness. For example, an infra-red filter to screen out the long wavelengths.

Additional flash blindness studies on the night problem be carried out at future tests as soon as laboratory work on animals has established suitable margins of safety from a retinal burn standpoint.

Retinal burn studies on animals be carried out in the laboratory to determine the retinal burn threshold, and that suitable field studies follow, using animals in actual atomic detonations.

Individuals performing military tasks and suspecting the imminence of an atomic flash make an effort to shield at least one eye from the light whether wearing red goggles or not.

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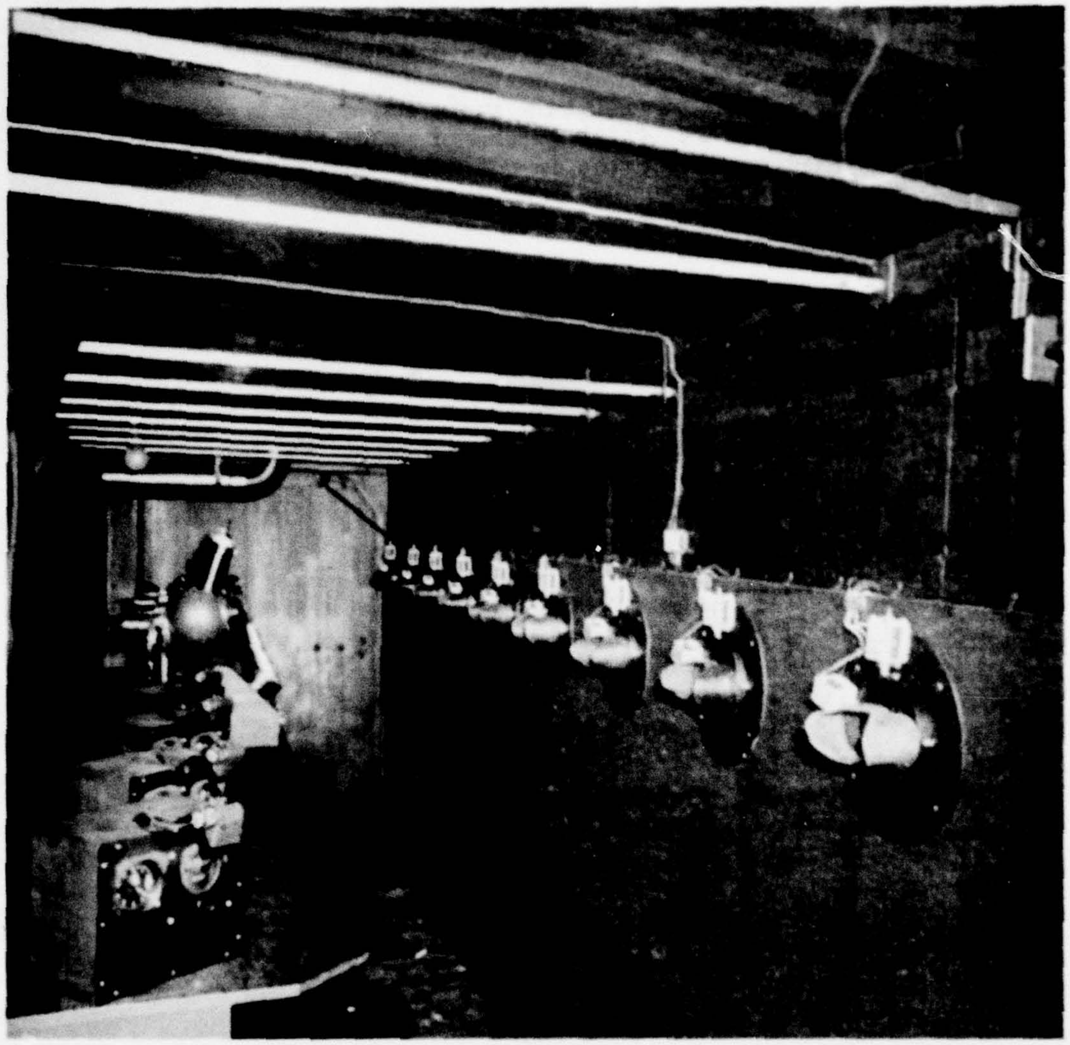

Fig. 1 Interior of light-tight trailer. The shutter mechanisms are on the right. The subjects were seated on stools which can be seen beneath the counter. After exposure they turned around and faced the test apparatus shown on the left. Stools were guided to the proper apparatus by tracks visible on the floor. The various sections were isolated from each other by the dark curtains on the sliding rods. The black stovepipe visible was a portion of the light-tight forced air ventilation system.

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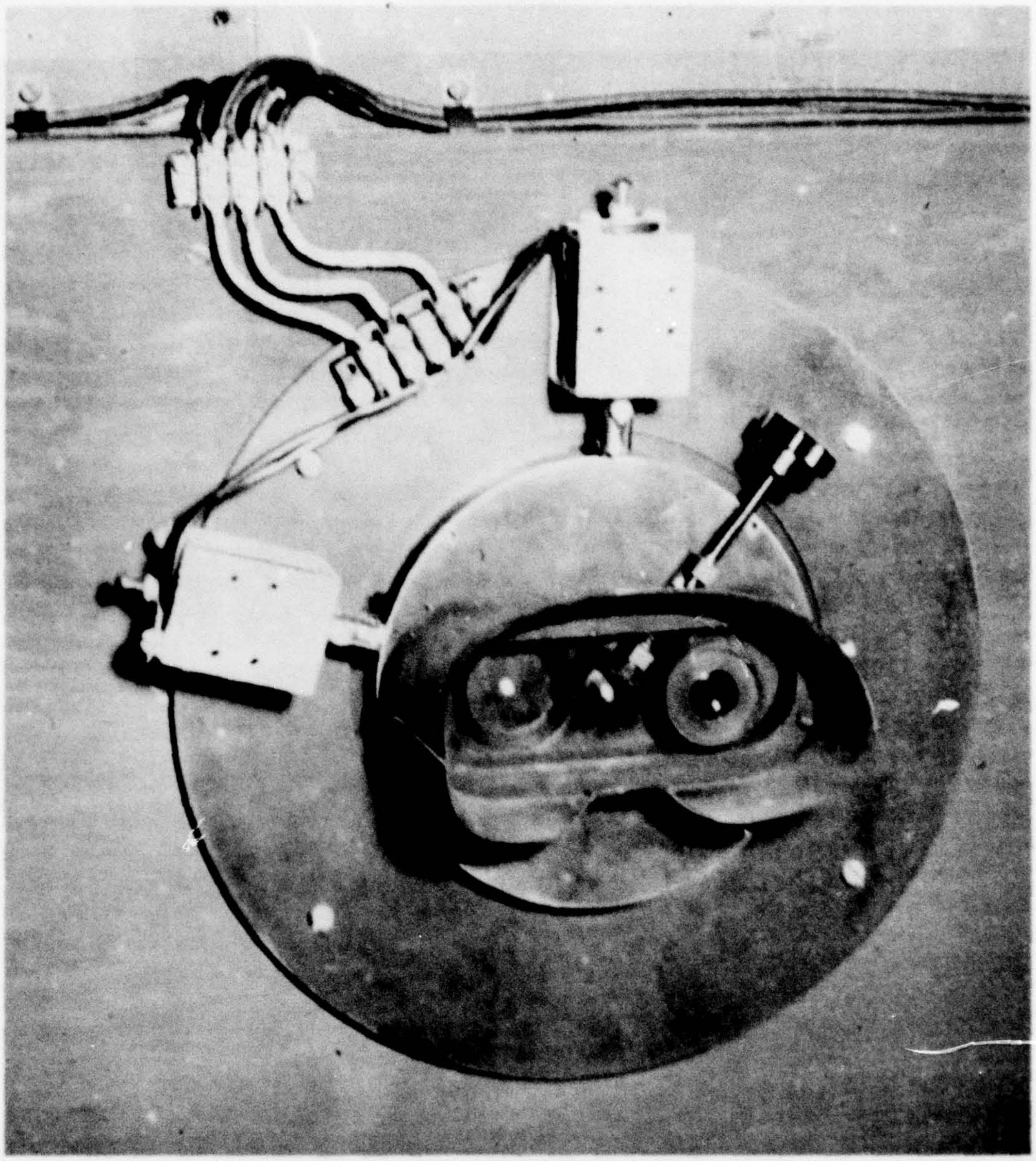

Fig. 2 Shutter Mechanism These shutters have a small self-luminous fixation spot before the right (unexposed) eye. This is brought to infinity by the strong plus lens shown. This device insures that the subject will be looking near, but not directly, at the detonation point and that his accommodation will be properly controlled. The shutters had an average opening lag of 48 milliseconds, remained open 2 seconds and closed again automatically.

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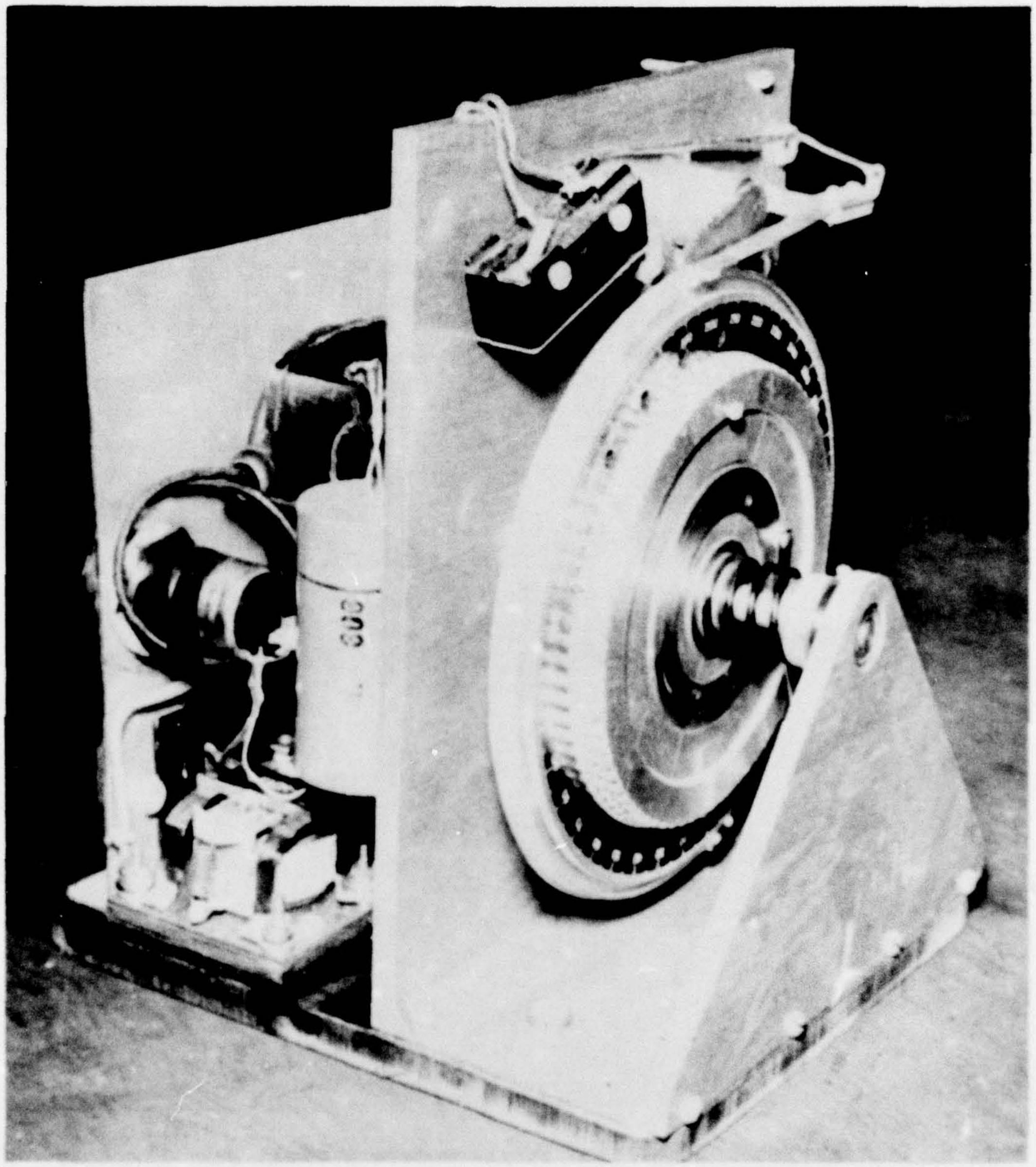

Fig 3 Shutter timing mechanism capable of taking any input signal of one second or less prior to detonation and activating the shutters. It has an accuracy of plus or minus one millisecond. It could not be used because of the inability to give an input signal at the test site of an accuracy better than plus or minus 100 milliseconds.

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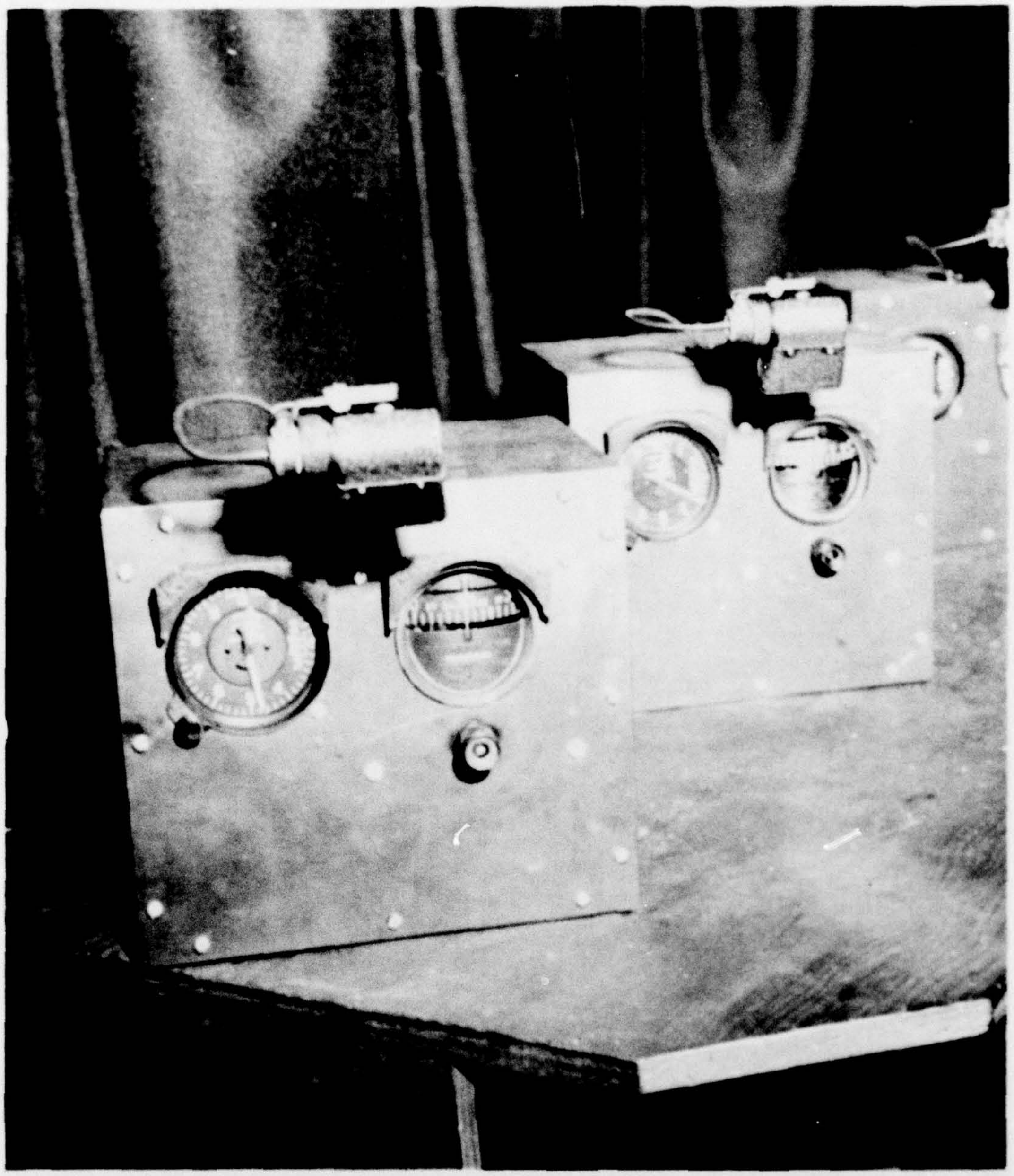

Fig 4 Aircraft instruments used in the instrument reading task. The red flood lighting and the individual instrument lighting sources are visible. Altimeter and gyro compass were selected because readings could be changed by the examiner and because they represent the typical instrument reading task of pilots.

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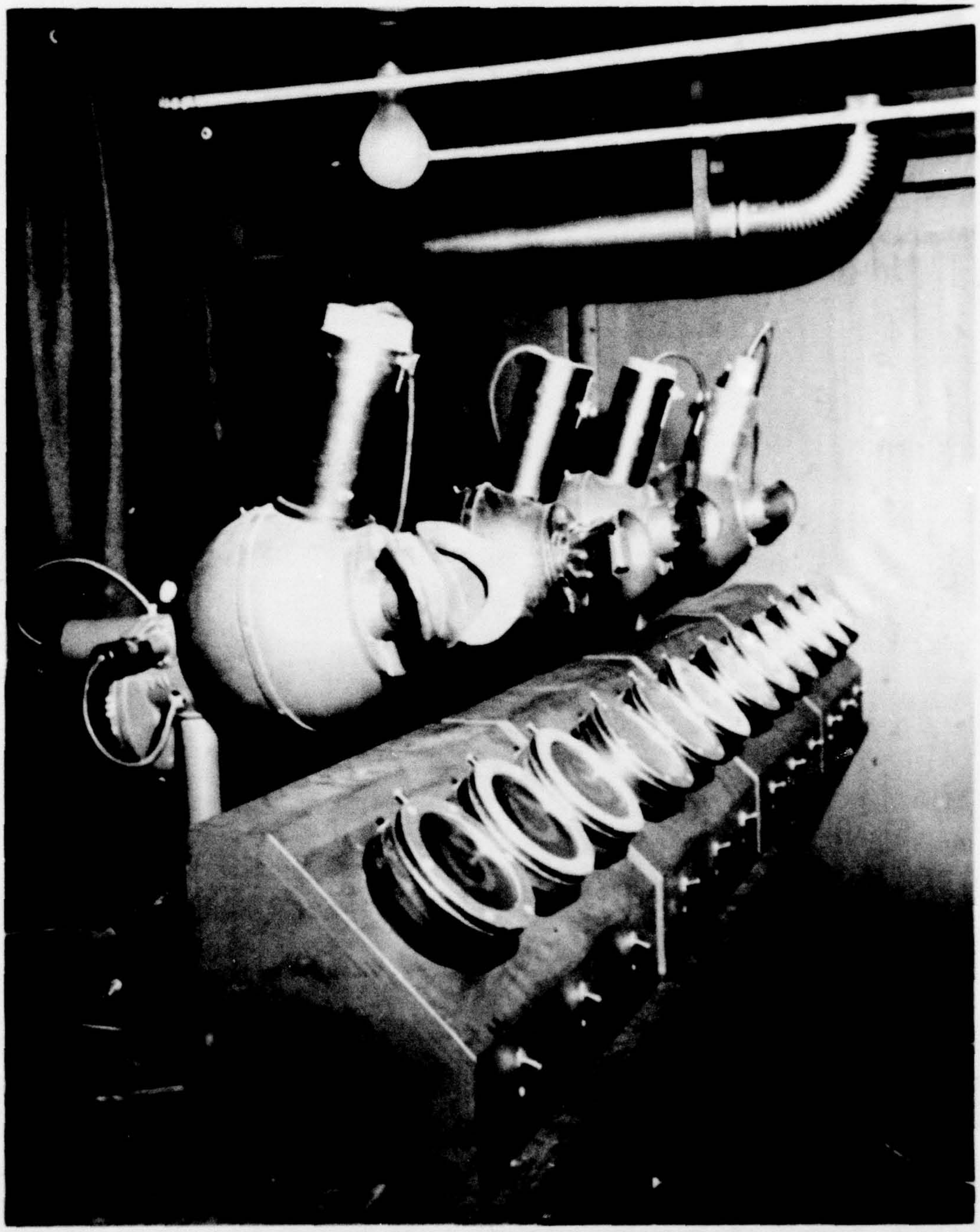

Fig 5 Battery of nyctometers and adaptometers These were used to plot the return of dark adaptation, both of the central and peripheral visual functions.

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Table I

Recovery of Ability to Read Red Lighted Instruments

SUBJECTS	Using Red Flood and Internal Lights	Using Internal Red Lights Alone
	Unprotected Group	
S	36 seconds	160 seconds
W	36 seconds	57 seconds
G	15 seconds	150 seconds
V	7 seconds	55 seconds
	Group Protected By Red Lenses	
A	7.5 seconds	80.5 seconds
A	5.5 seconds	77.5 seconds
V	13 seconds	90 seconds
V	6 seconds	55 seconds

Times listed are from detonation to first correct reading.

[redacted]

Table II

Recovery of Mesopic Vision Measured on the Nyctometer

Subjects	Visual Acuity 0.1	0.2	0.3	0.4	0.5	0.6	0.7
Unprotected Group							
A.T.	52 sec	85 sec	150 sec	190 sec	240 sec		
G.B.	10 sec	20 sec	60 sec	90 sec	230 sec		
A.T.	12 sec	18 sec	60 sec	110 sec	245 sec		
G.B.	40 sec	50 sec	90 sec	136 sec	240 sec		
Group Protected by Red Lenses							
R.B.	16 sec	18 sec	30 sec	135 sec	240 sec		
M.S.	10.3 sec	90 sec	120 sec	150 sec	225 sec		
R.B.	12 sec	12 sec	21 sec	38 sec	180 sec		
M.S.	30 sec	75 sec	105 sec	120 sec	135 sec	190 sec	210 sec

Times listed are from detonation to first correct reading. Test was discontinued in all cases at the end of 4 minutes.

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Table III

Recovery of Scotopic Vision Measured on the Adaptometer

	Unprotected Group			
	0.001 Foot-candle of illumination approximately		0.00001 Foot-candle of illumination approximately	
SUBJECTS	Distinguish Light	Distinguish Form	Distinguish Light	Distinguish Form
A.T.	4 min, 30 sec	6 min, 4 sec	9 min, 30 sec	20 min
A.T.	3 min, 30 sec	3 min, 50 sec	4 min 30 sec	7 min, 13 sec
G.B.	4 min, 20 sec	4 min, 40 sec	6 min, 50 sec	9 min, 50 sec
J.B.	4 min	5 min, 30 sec	6 min, 7 sec	7 min, 40 sec
	Group Protected by Red Lenses			
R.B.	4 min, 20 sec	4 min, 20 sec	5 min	5 min
M.S.	4 min, 30 sec	4 min, 30 sec	4 min, 43 sec	5 min, 30 sec
R.B.	3 min, 30 sec	3 min, 30 sec	3 min, 35 sec	3 min, 40 sec
M.S.	4 min	4 min	4 min, 30 sec	4 min, 30 sec

Times listed are from detonation to first correct reading.

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